Effects of gestational energy source on feedlot performance, glucose tolerance, and carcass traits of progeny

Honors Thesis

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By

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Chapter 1

Literature Review

Introduction

U.S. beef producers are currently facing all time high corn prices and slim profit margins as well as pressure to produce a high quality retail product. In order to meet the expectations of consumers and remain profitable to stay in business, improved nutrition and management are vital to yielding an acceptable product. Nutritional management at the prenatal level can impact the quality characteristics of the weaned calf. For example, higher gestational nutrient load is correlated to increased weaning weight and improved calf health (Corah et al., 1975).

Other studies suggest that maternal diet can impact the carcass composition of progeny at birth (Wu et al., 2006). Maternal diet protein, specifically, is an individual nutrient that is associated with progeny growth and carcass composition (Larson et al., 2009). Wallace et al. (2004) found that over or under nutrition of cows can lead to Intra Uterine Growth Retardation (IUGR). In looking at a review of IUGR, Wu et al. (2006) cites evidence that suggests fetal gene expression may be altered by the intrauterine environment.

Fetal programming has the potential to have a tremendous impact on the meat industry. Knowledge of the effect of cow nutrition on carcass quality of the progeny would allow producers to choose diet rations and feedstuffs that allow them to maximize their return. However, more research is needed to clarify the relationship of nutritional status and specific gestational energy source on postnatal fat and muscle development.

Effects of maternal prepartum nutrition on offspring

Dr. David Barker defined fetal programming as a maternal insult or stimulus that has lifelong impacts to the progeny (Barker et al., 1993; Godfrey & Barker, 2000). Maternal nutrient restriction during gestation has been shown to negatively impact growth rate, muscle mass, and health of progeny (reviewed by Wu et al., 2006). The effects of moderate changes or differing energy sources in the dam's nutrition during gestation on postnatal progeny performance are not known.

Fetal development of skeletal muscle

Skeletal muscle growth is primarily responsible for 90% of the fetal body weight gained in the last 40 days of gestation (Bell et al., 2005). Muscle grows in a combination of three factors: increased muscle cell number (hyperplasia), increased muscle cell size (hypertrophy), and change in muscle synthesis and/or breakdown. Of these three factors, hyperplasia and hypertrophy have the highest impact on muscle mass.

Muscle cell hyperplasia is fixed by birth. Primary myofibers are formed first, followed by secondary myofibers during prenatal development (Beermann et al., 1978). Severe undernutrition in pigs has been shown to reduce muscle fiber number (Wigmore and Strickland, 1983) whereas increased nutrient availability to the fetus, via treatment of growth hormone on the sow, can increase muscle fiber number in piglets (Rehfeldt et al., 2004).

The effect of maternal nutrition on muscle cell hypertrophy is not well documented. Nutrient restricted ewes had progeny with a similar muscle fiber number but reduced fiber diameter and sarcomere length (Nordby et al., 1987). Costello (2008), in contrast, observed that nutrient restriction resulted in less myofibers in lambs. From a standpoint of meat quality, enhanced muscle fiber size can have an impact on tenderness. It would be ideal to maximize muscle cell hyperplasia in a developing fetus without compromising meat quality via hypertrophy.

Fetal development of adipose tissue

The development of fat tissue (adipogenesis) begins during mid-gestation (Gnanalingham et al., 2005). Growth of fat tissue continues post natally due to both hypertrophy and hyperplasia (Feve, 2005). Nutrient restriction in ewes during early gestation yielded progeny with more adipose tissue at birth (Bispham et al., 2003). Cows which were on a restricted nutrient status during gestation had progeny with less external fat compared to intramuscular and internal fat (Underwood et al., 2008). This indicates that the maternal diet may impact the location of fat accretion within the progeny.

Fetal programming on livestock production traits

The mechanism of how gestational nutrition affects the growth of progeny is not clearly known. Evidence suggests maternal nutrition influences birth weight of progeny (Collier et al., 1982) which can impact growth throughout the animal's lifetime. Nutrient restriction in pregnant ewes resulted in lambs with similar birth weights but with less muscle and more intramuscular fat at time of harvest (Ford et al., 2007). Amount of energy in gestation diets can also impact calf performance. Feeding a high energy diet to pregnant cows was shown to increase birth and weaning weight (Corah et al., 1975). The effect of feeding specific sources of energy to pregnant cows on progeny growth and performance has not been investigated until recently at The Ohio State University. The most common and cost effective dietary energy sources for cows are hay, corn, and DDGS. Hay provides most of its calories from forage fermentation, corn provides most of its calories from starch fermentation, and DDGS provides most of its calories from fiber, protein, and oil. Thus, these three feedstuffs present distinct metabolic substrates as sources of energy for the cow and her developing fetus.

Insulin Resistance and Adipogenesis

The relationship of obesity to insulin resistance and Type 2 diabetes has long been recognized. Research over the last two decades has revealed that adipocytes act as an endocrine cell, secreting compounds like leptin, resistin, and complement-related proteins (Miner, 2004). Resistin is a protein that can cause insulin resistance across the whole body (Miner, 2004). Recent research is being done with thiazolidinedione (TZD) which is a compound found to improve insulin sensitivity by inhibiting resistin production (Miner, 2004). Not only is this drug beneficial as a treatment for Type 2 diabetes, it has also been indicated to enhance intramuscular fat deposits in swine (Hausman et al., 2008).

The relationship of adipocytes and insulin resistance is complex. Insulin resistance can arise due to excess or absence of fat (Kahn, 2000). Evidence has shown that location of fat depot is also significant in impacting insulin resistance. Central or intra-abdominal fat has been linked to increased insulin resistance, Type 2 diabetes, and cardiovascular disease (Kahn, 2000). One hypothesis regarding the adipo-insulin axis (Kahn, 2000) is that there is an unknown common factor acting between insulin resistance and adipogenesis. Another is that adipocytes (specifically those located centrally) have a unique biochemical role that directly influences insulin sensitivity (Kahn, 2000). Further work is needed to elucidate the relationship between insulin resistance and adipogenesis. In cattle, adipogenesis is desirable in the intramuscular depot (increasing beef palatability and carcass value) while being detrimental in the subcutaneous depot (decreasing retail yield and carcass value). Limited data are available on the role of insulin resistance in adipogenesis in these two depots during the feeding period for feedlot cattle.

Conclusion

The evidence cited above shows that gestational nutrient status can affect the growth and development of offspring. While the entire mechanism is not understood, gestational diet has an effect on muscle development and fat accretion in progeny, which correlates to dollars gained or lost to a producer. A relationship between insulin resistance and adipogenesis has also been recognized, but its role in fattening of beef cattle has not been elucidated. Research is needed to investigate the effects of maternal dietary energy source on subsequent growth of progeny to determine optimal and economical feedstuffs that will capitalize on positive aspects of fetal programming as well as to study the effect of time of exposure to a grain based diet during the finishing phase on insulin resistance and adipogenesis in feedlot cattle.

Chapter 2

Effects of gestational energy source on feedlot performance, glucose tolerance, and carcass traits of progeny

Abstract

Effects of maternal energy source during gestation on postnatal growth and metabolism of progeny has not been well described. The objectives of this experiment were to determine the effects of hay (HAY), corn (CORN), or dried distillers grains (DDGS) fed to cows in late-gestation on progeny post-weaning growth, glucose tolerance, and carcass characteristics. Angus-cross cows (n = 84; BW = 620 ± 12 kg) were blocked by BW and allotted to 4 pens per treatment. Dietary treatments were fed at isocaloric intakes from 155 to 272 d of gestation. Following parturition, cows and calves were fed and managed as 1 group. Post-weaning, steers (n = 27) and heifers (n = 27) were transported to the feedlot, housed in individual pens, and fed a common diet which contained 50% cracked corn, 20% DDGS, 15% corn silage, and 15% supplement (DM basis). A glucose tolerance test (GTT) was conducted on calves (n = 12) on d 41 and d 111 after feedlot arrival and blood samples (n = 7) from each calf were collected from 5 to 120 min post-glucose intravenous infusion (0.25 g of glucose/kg of BW). Calves were slaughtered at a 12th rib fat thickness of 1.2 ± 0.05 cm as determined via ultrasound. Gestational diet did not affect ($P \geq 0.30$) progeny feedlot performance (initial BW, final BW, DMI, ADG, or G:F). During the GTT, fasting concentration and area under the curve (AUC) for glucose and insulin were not affected ($P \geq 0.47$) by treatment. Glucose clearance rate was greater ($P = 0.01$) in progeny from dams fed CORN than progeny from dams fed HAY or DDGS. Initial insulin response was greatest to least ($P < 0.01$) for calves from cows fed CORN, DDGS, and HAY, respectively. Fasting insulin, insulin AUC, glucose AUC, and glucose clearance rate were all greater ($P < 0.01$) on d 111 than d 41. There were no differences ($P \geq 0.33$) among treatments for carcass characteristics. Gestational energy source did not affect feedlot performance or carcass traits; however, it did affect glucose clearance rate and initial insulin response. Days on feed increased insulin resistance and decreased glucose tolerance when cattle were fed a high-grain diet.

Introduction

Fetal programming is when a stimulus or insult during gestation has lifelong effects. Reduced fetal growth in humans has been linked to higher death rates from cardiovascular disease, increased hypertension, and increased type 2 diabetes. This is known as the Barker hypothesis (Barker, 1993). In cattle, source of energy in late gestation diets may impact fat accretion of progeny by altering insulin sensitivity (Radunz, 2009). It is known that growth rate and composition of growth affect feedlot profitability. However, there is limited information regarding the effect of gestation energy source on growth and development of progeny as well as the effect of days on feed on insulin sensitivity and adipogenesis.

Objectives

Our objectives were:

1) To determine effects of cow gestation diet on feedlot performance, glucose tolerance, and carcass composition of progeny.

2) To determine effect of days on feed on Glucose Tolerance and the relationship of GT with carcass characteristics.

Materials and Methods

Treatments

Eighty- four Angus cross cows were placed on treatment diets composed mainly of hay, corn, or dried distiller's grains with solubles (DDGS). Hay was fed ad libitum; corn and DDGS were limit fed at isocaloric intakes (Table 1). Treatment diets were imposed from day 155 to day 272 of gestation and cows were managed as one group following parturition. We chose these feed commodities because they are economical and provided a diverse nutrient composition of fiber, fat, starch, and protein.

Table 1. Cow nutrient intake during gestation

Item	Hay	Corn	DDGS
Total Intake, kg/d	12.8	7.8	6.8
Hay, kg/d	12.8	2.2	2.0
Corn, kg/d	---	4.6	---
DDGS, kg/d	---	---	3.9
Supplement, kg/d	---	1.0	0.9

Performance

After weaning, fifty- four calves were transported to the OARDC feedlot and individually fed the same feedlot diet composed of 50% corn, 20% DDGS, 15% corn silage, and 15% supplement. Dry matter intake was recorded daily and body weight was measured every 28 days. The experimental design was a Completely Randomized Design. Data were analyzed using Proc Mixed and calf was the experimental unit.

Carcass Characteristics

Calves were harvested individually after reaching a target backfat of 1.2 cm as determined by ultrasound. Carcass characteristics were measured after a 48 hour chill and

Intramuscular fat (IMF) content was determined by ether extract from a Longissimus muscle sample taken at the 12th rib.

Glucose Tolerance

Two glucose tolerance tests (GTT) were conducted on day 41 and day 111 after feedlot arrival. Glucose was infused intravenously at 0.25 g/kg BW following a 24 hr fast. Seven blood samples were collected between 5 and 120 minutes post-infusion.

Plasma Analysis

Blood plasma was analyzed for concentration measures of glucose and insulin. Insulin was measured using the Mercodia Bovine Insulin ELISA assay and glucose was measured using a Glucose Liquicolor Kit from Stanbio. Both assays were carried out on a 96 well plate reader.

Results

Effects of Cow Gestation Diet on Progeny Performance and Carcass Characteristics

There was no effect of diet on feedlot performance of progeny (Table 2). Calves of mothers from all three treatments entered the feedlot at approximately 213 kilograms (kg) and were harvested at approximately 484 kg. Days on feed, average daily gain, dry matter intake, and gain/feed were also not effected by gestation diet.

Table 2. Effect of cow gestation diet on feedlot performance of progeny

Item	**Hay**	**Corn**	**DDGS**	***P*-value**
No. calves	18	18	18	----
Initial body weight, kg	210	214	216	0.74
Final body weight, kg	495	476	480	0.51
Days on feed	181	164	164	0.25
Average daily gain, kg	1.59	1.62	1.63	0.82
Dry matter intake, kg	7.7	7.6	7.8	0.89
Gain/Feed, kg/kg	0.206	0.212	0.210	0.31

Aside from the carcass weight, yield and quality grade have the biggest impact on carcass value. This table shows that there were no gestational diet effects on the carcass quality and yield characteristics. We saw no effect of cow gestation diet on Hot Carcass Weight, Kidney/Pelvic/Heart Fat, and Longissimus Muscle Area. Dressing percentage was highest in progeny from cows fed Hay. Despite our efforts to harvest cattle at the same backfat, calves from cows fed Hay ended up with slightly higher backfat. This may explain the higher dressing percentage we observed. The cattle across all treatments had an average yield grade of 3.2 and the % of carcasses grading select ranged from 2.7 of progeny of cows fed HAY to 22.2% of progeny of cows fed corn.

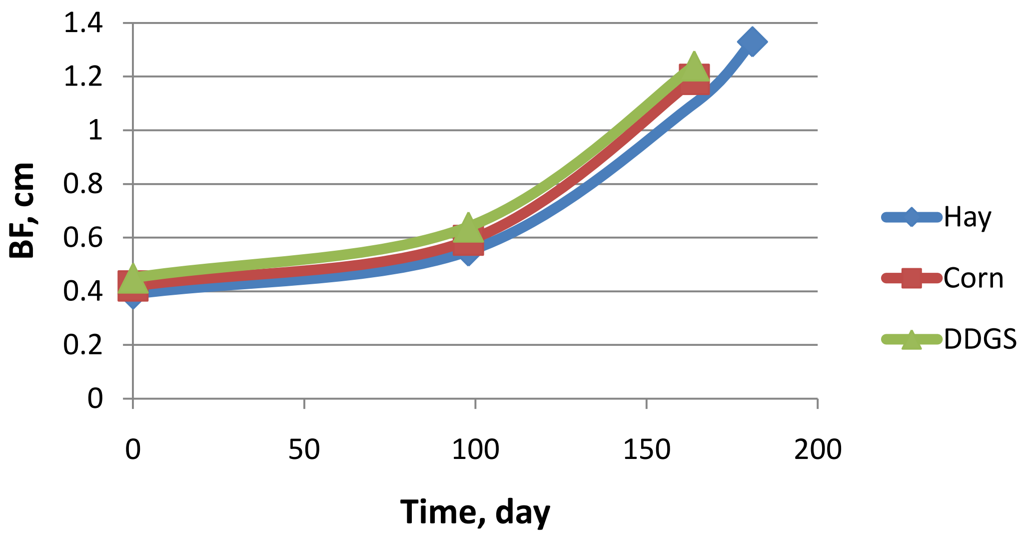
Table 3. Effect of cow gestation diet on carcass characteristics of progeny

Item	**Hay**	**Corn**	**DDGS**	***P*-value**
Hot Carcass Weight, kg	303.6	288.6	288.4	0.33
Dressing %	61.3 ^{a}	60.5 ^{ab}	60.0 ^{b}	0.03
Kidney/Pelvic/Heart Fat, %	3.4	3.5	3.7	0.63
Longissimus Muscle, cm^2	76.9	73.4	74.7	0.46
USDA Yield Grade	3.2	3.2	3.2	0.88
Marbling Score[c]	591	546	576	0.36
Intramuscular Fat, %[d]	4.70	4.39	4.74	0.77
% Select	2.7	22.2	14.0	0.21

[a,b] Means within a row with different superscripts differ ($P < 0.05$)
[c] 500-590= Small
[d] Ether extract of LM at 12th rib

The figure below shows progeny backfat accretion from day 0 of feedlot arrival to the day of slaughter. The slopes are not linear and rates of backfat accretion increase rapidly from day 111 to harvest.

Figure 1. Effects of cow gestation diet on progeny backfat accretion



Effects of Days on Feed on Insulin and Glucose Response

Figure 2 shows the response of insulin to glucose dose. The curves in Figure 2 were used to generate the data in Table 4. Fasting insulin before glucose infusion was .79 µg/L on day 41 and increased to 2.1 µg/L on day 111. The initial response to glucose infusion was almost double on day 111 compared to day 41 on feed. Total Insulin Area Under the Curve went from 367 units on day 41 to 851 on day 111. These data suggest that with increasing days on feed, insulin response also increased.

Figure 2. Effect of Days on Feed on Insulin Response

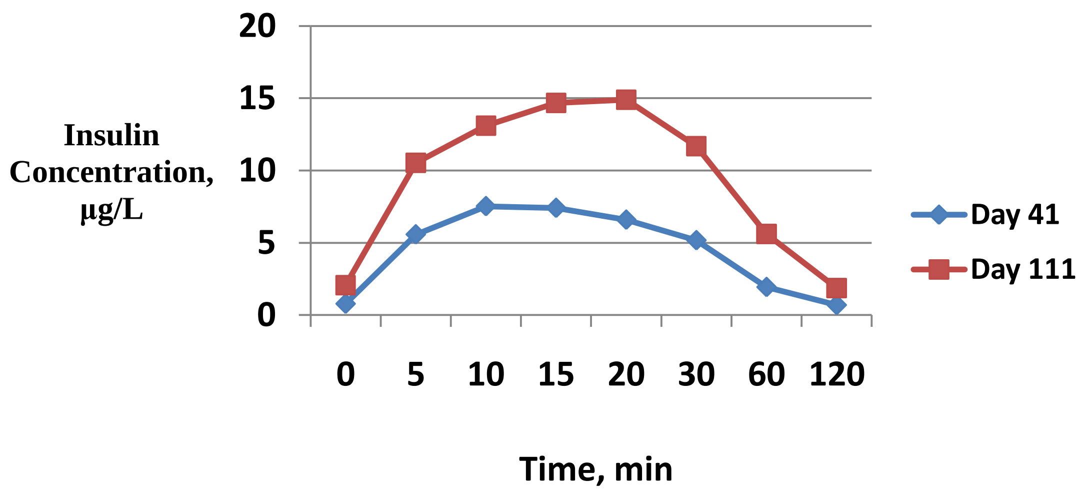


Table 4. Main Effect of Days on Feed on Insulin Response

Insulin	**Day 41**	**Day 111**	***P*-Value**
Fasted, µg/L	0.79	2.1	0.01
Initial Response, µg/L	12.3	21.6	0.006
Total AUC	367	851	0.0001

Figure 3 shows the glucose response after glucose infusion. These glucose responses to the Glucose Tolerance Tests were used to generate Table 5. Table 5 indicates that there was no effect of days on feed on fasted blood glucose concentration. Glucose clearance rate to the glucose infusion was 25% greater on day 111 than on day 41. Total Glucose Area Under the Curve (AUC) was also greater on day 111 than on day 41. The Insulin: Glucose AUC ratio is a measure of insulin resistance. This ratio was .023 for calves on day 41 and, on day 111, this ratio had doubled to .049. This suggests it took twice as much insulin per unit of glucose on day 111. Overall this implies that these calves were becoming insulin resistant. Considering Figure 1, after day 111, BF accretion was also increasing rapidly. This suggests a possible relationship between insulin resistance and adipogenesis in feedlot cattle.

Figure 3. Effect of Days on Feed on Glucose Response

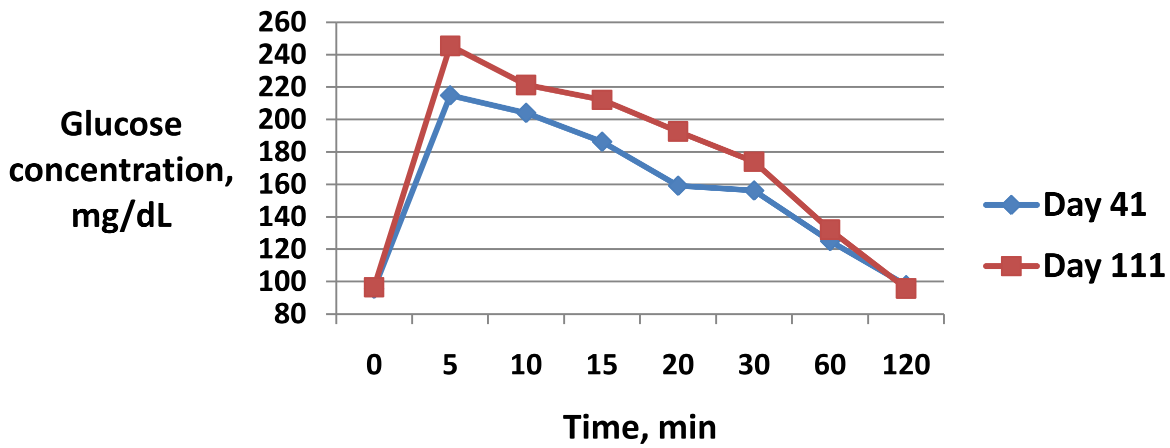


Table 5. Main Effect of Days on Feed on Glucose Response

Glucose	Day 41	Day 111	P-Value
Fasted, mg/dL	95.6	96.5	.84
Clearance, mg/min	0.93	1.17	< .001
Total AUC	16,143	17,365	.02
Ins:Glc AUC	.023	.049	.0002

Effect of Cow Gestation Diet on Insulin and Glucose Response

Table 6 indicates that there were no differences due to cow diet on fasted insulin concentration, initial response to insulin of glucose infusion, or Total Insulin AUC following glucose infusion. Likewise, Table 7 shows cow gestation diet did not affect fasted glucose concentration or Total Glucose AUC following glucose infusion. Progeny in cows fed CORN had a higher glucose clearance of 1.13 than progeny of cows fed Hay or DDGS. Despite these differences in clearance rate, the insulin to glucose AUC ratio was not affected by cow gestation diet suggesting there was no effect of cow gestation diet on insulin resistance.

Table 6. Effect of Cow Gestation Diet on Insulin Response

Insulin	**Hay**	**Corn**	**DDGS**	***P*-Value**
Fasted, µg/L	0.95	1.89	1.45	0.46
Initial Response, µg/L	11.0	20.6	19.2	0.29
Total AUC	475	670	681	0.64

Table 7. Effect of Cow Gestation Diet on Glucose Response

Glucose	**Hay**	**Corn**	**DDGS**	**P-Value**
Fasted, mg/dL	96.1	98.4	93.6	0.67
Clearance, mg/min	1.01^{a}	1.13^{b}	1.06^{a}	< 0.01
Total AUC	16,708	16,849	16,705	0.98
Ins: Glc AUC	0.028	0.040	0.040	0.67

Conclusions

Source of gestational energy did not affect performance or carcass characteristics of progeny. Gestational energy also did not impact insulin response in progeny due to glucose infusion. Glucose clearance was faster in progeny from cows fed CORN compared to progeny from cows fed HAY or DDGS.

Increasing days on feed was associated with increased insulin response to glucose infusion, increased glucose AUC and clearance rate, and a higher Insulin:Glucose AUC. This indicates that cattle were becoming less glucose tolerant and more insulin resistant over time. Increasing insulin resistance may explain adipogenesis in finishing feedlot cattle.

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